



US006650587B2

(12) **United States Patent**  
**Derner et al.**

(10) **Patent No.:** **US 6,650,587 B2**  
(45) **Date of Patent:** **Nov. 18, 2003**

(54) **PARTIAL ARRAY SELF-REFRESH**

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(21) Appl. No.: **09/988,988**

(57) **ABSTRACT**

(22) Filed: **Nov. 19, 2001**

A memory device includes an address selection circuit to store addresses of selected rows of memory cells. During a refresh mode, only the memory cells of the selected rows are refreshed. The addresses of the selected rows can be stored by a user or automatically.

(65) **Prior Publication Data**

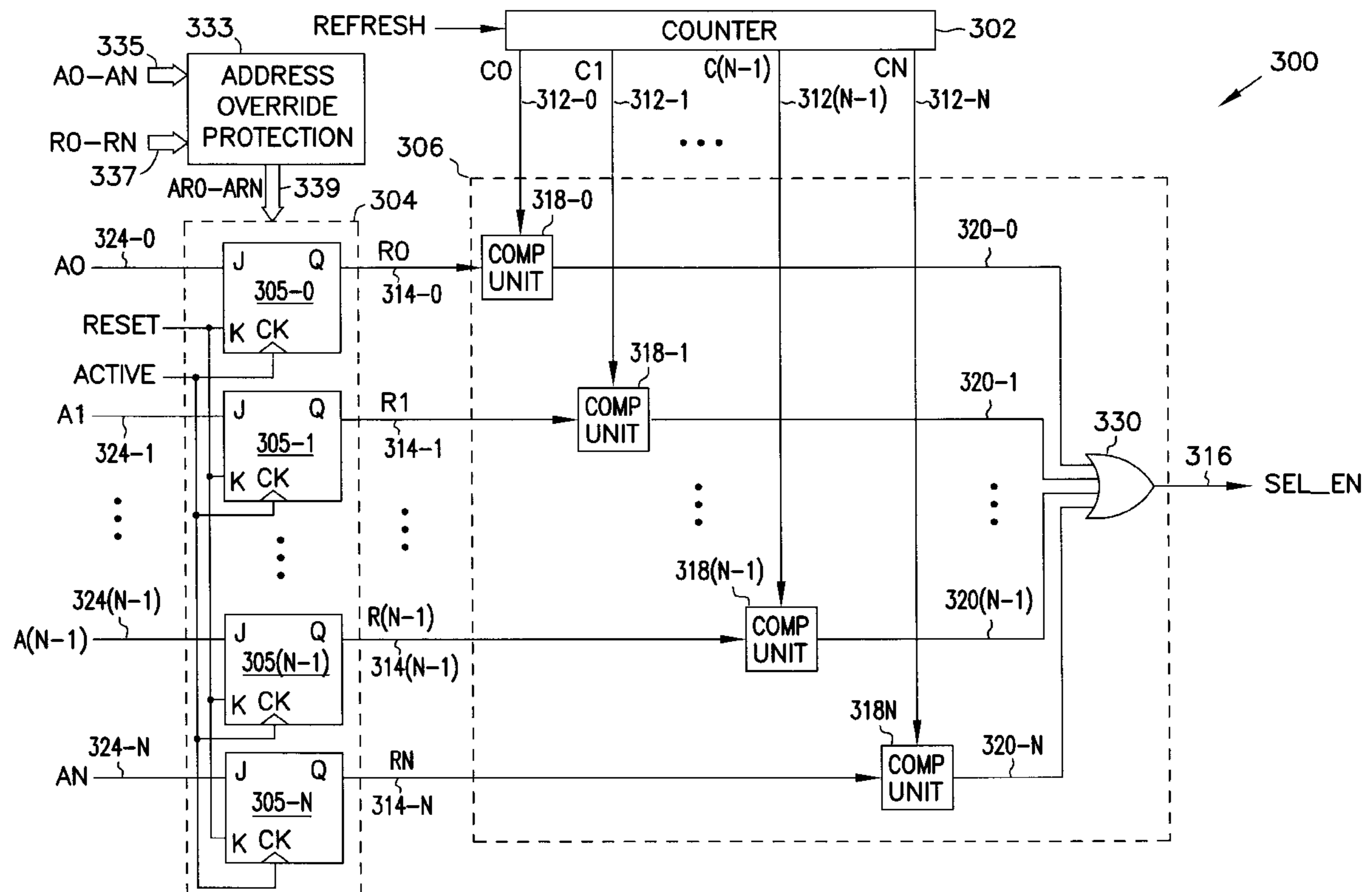
US 2003/0095459 A1 May 22, 2003

(51) Int. Cl.<sup>7</sup> ..... **G11C 7/00**

(52) U.S. Cl. .... **365/222; 365/236**

(58) Field of Search ..... **365/222, 236**

**49 Claims, 10 Drawing Sheets**



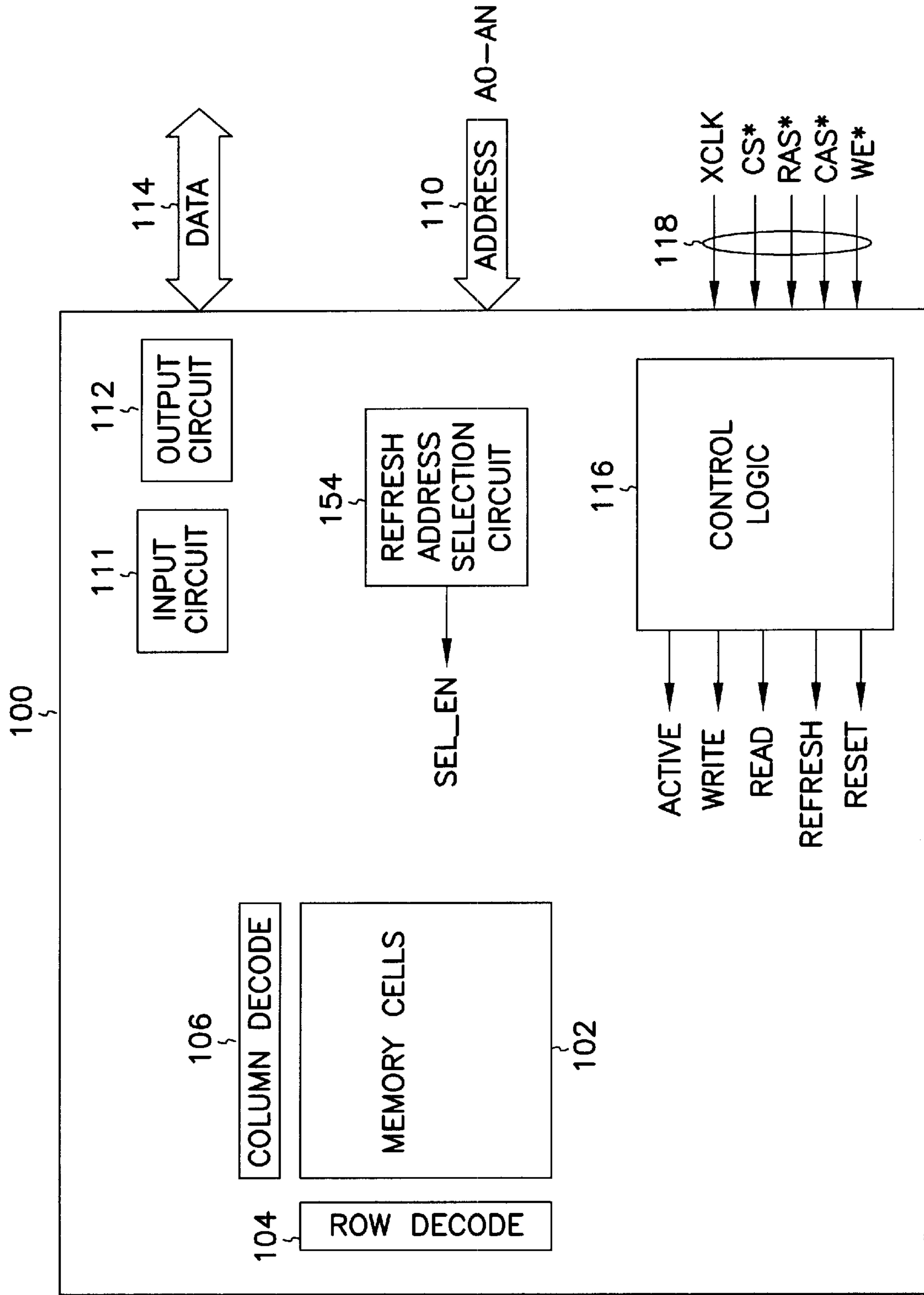


FIG. 1

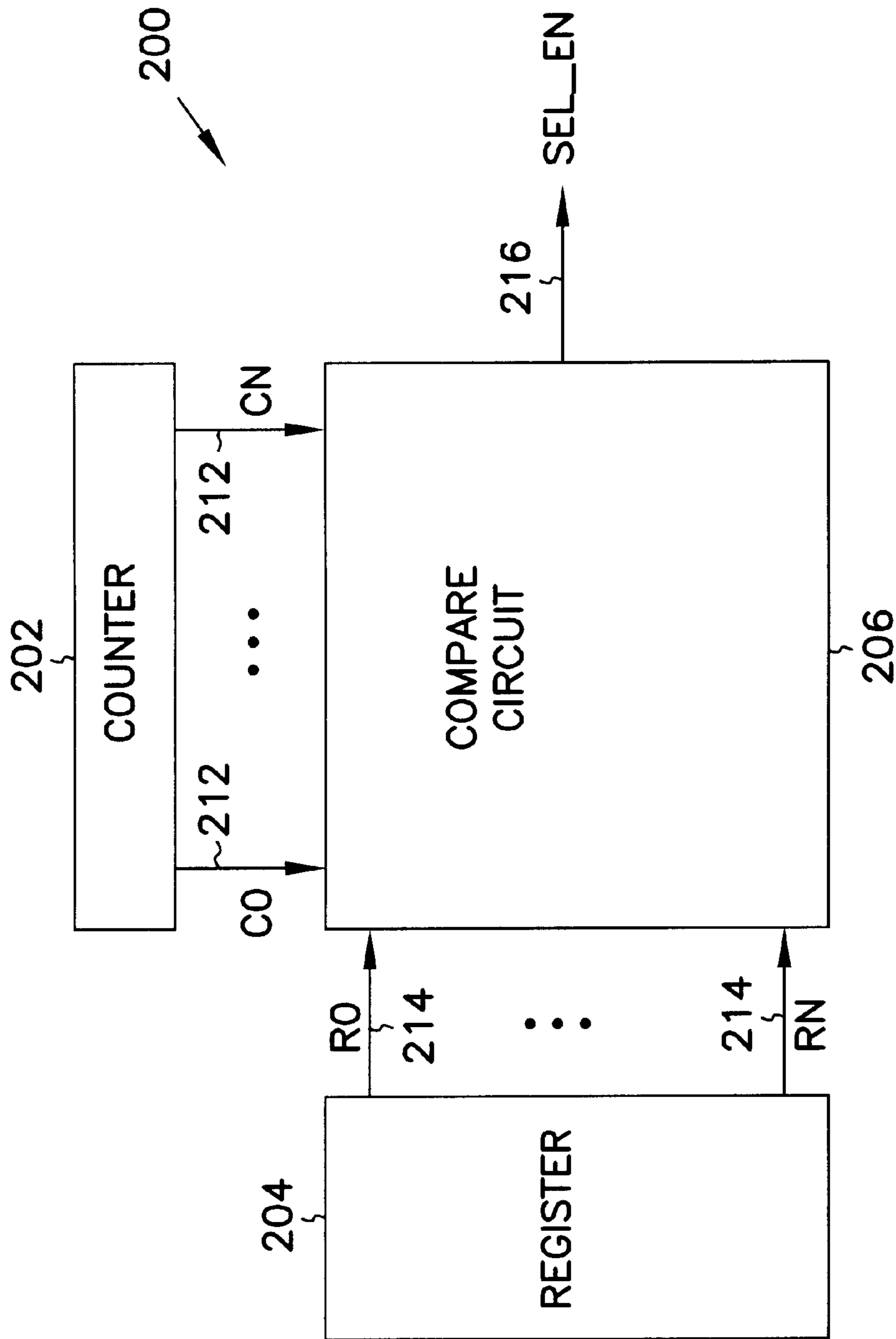


FIG. 2

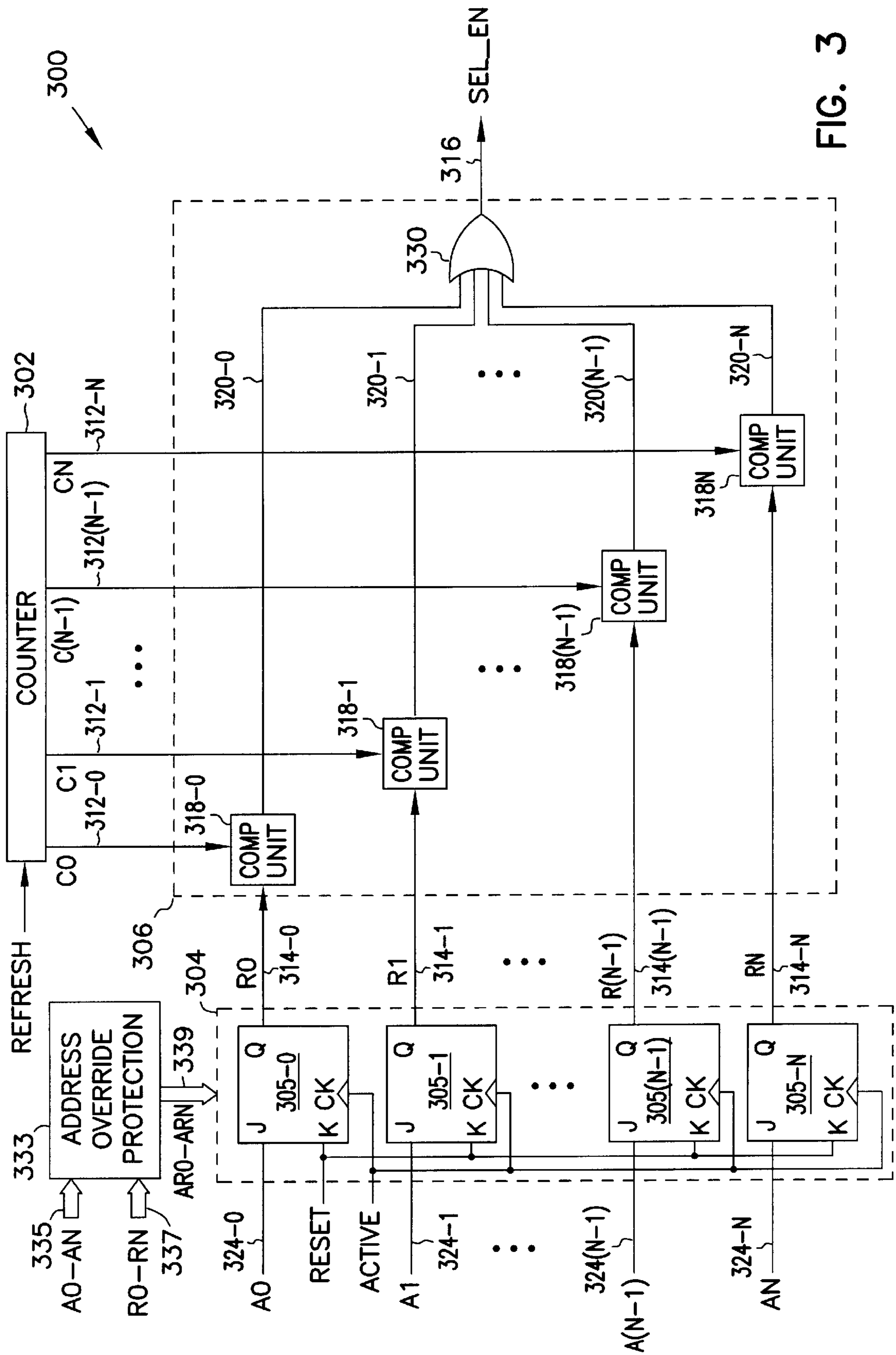


FIG. 3

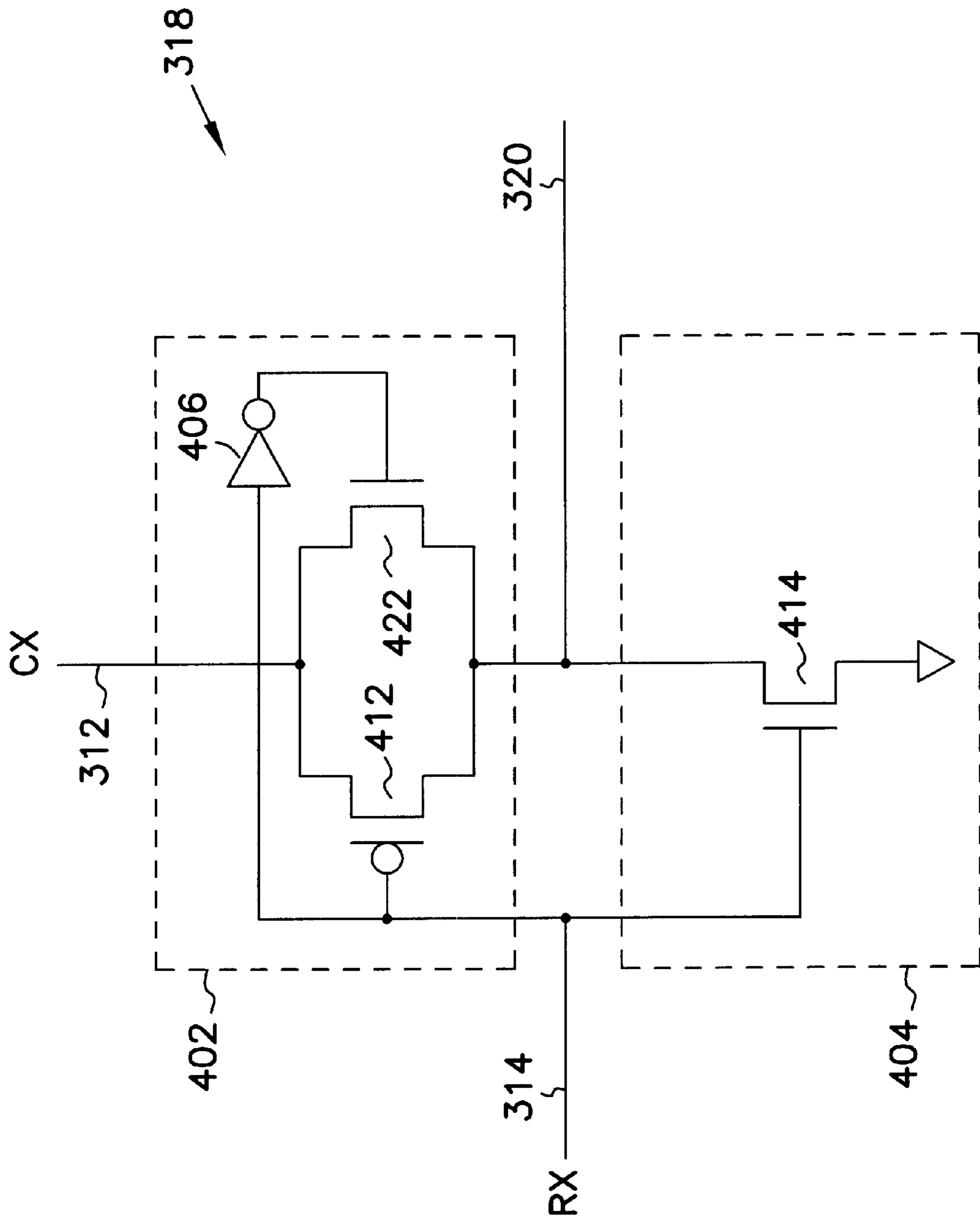


FIG. 4

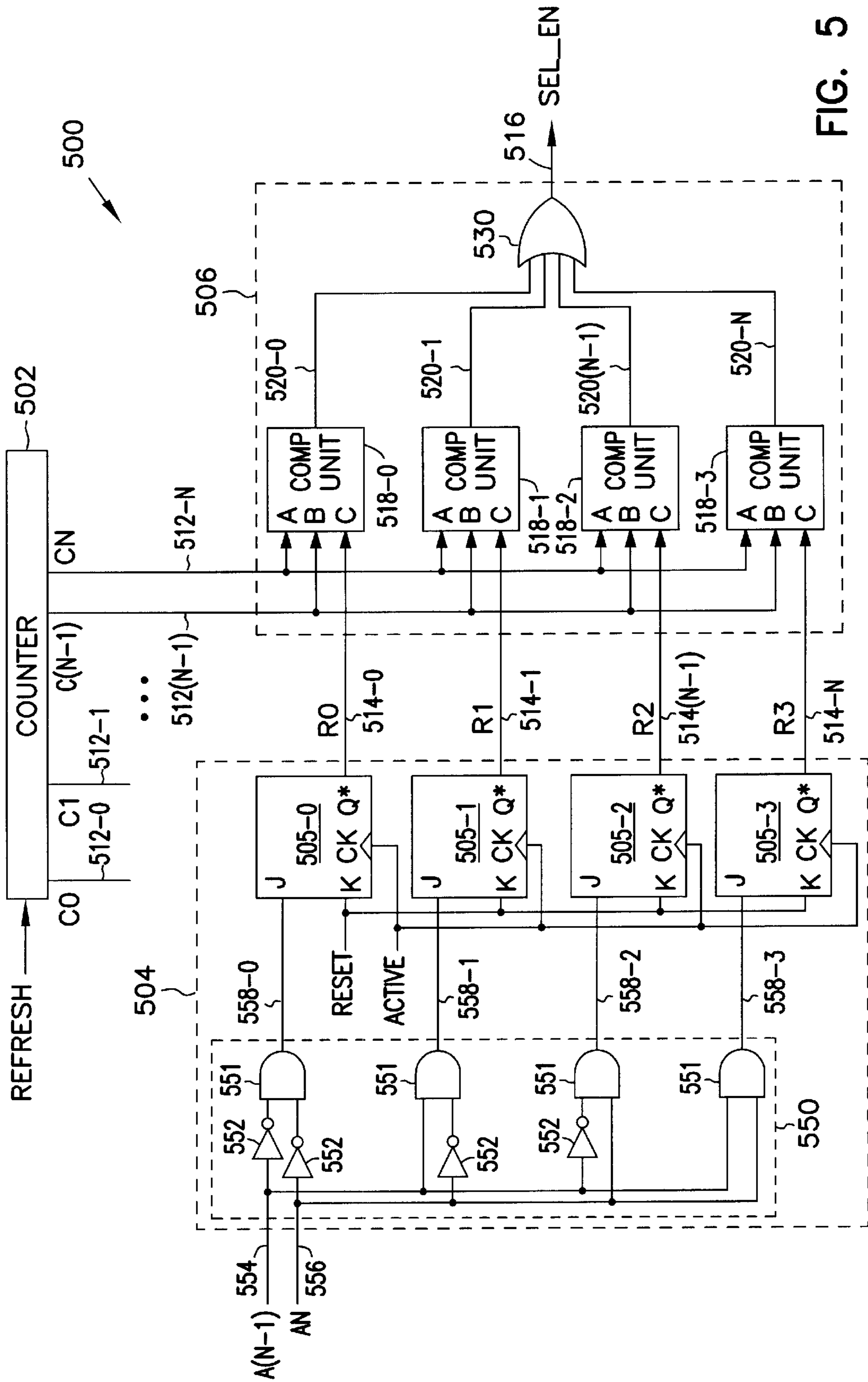


FIG. 5

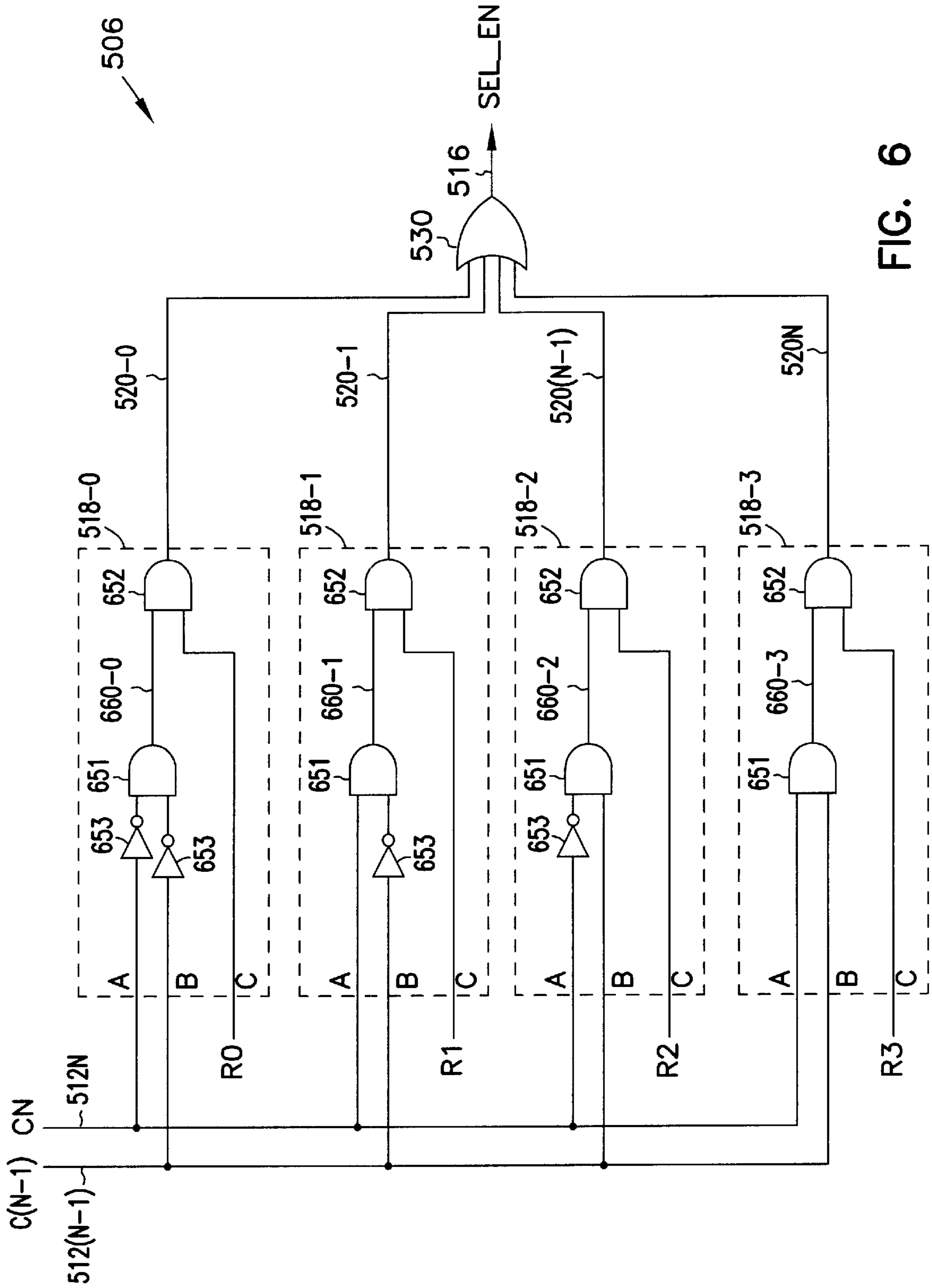


FIG. 6



RANGE	ROWS
0	0-511
1	512-1023
2	1024-1535
3	1536-2047

FIG. 7

ROW ADDRESS BITS	ROWS
00XXXXXXXXXX	0-511
01XXXXXXXXXX	512-1023
10XXXXXXXXXX	1024-1535
11XXXXXXXXXX	1536-2047

FIG. 8



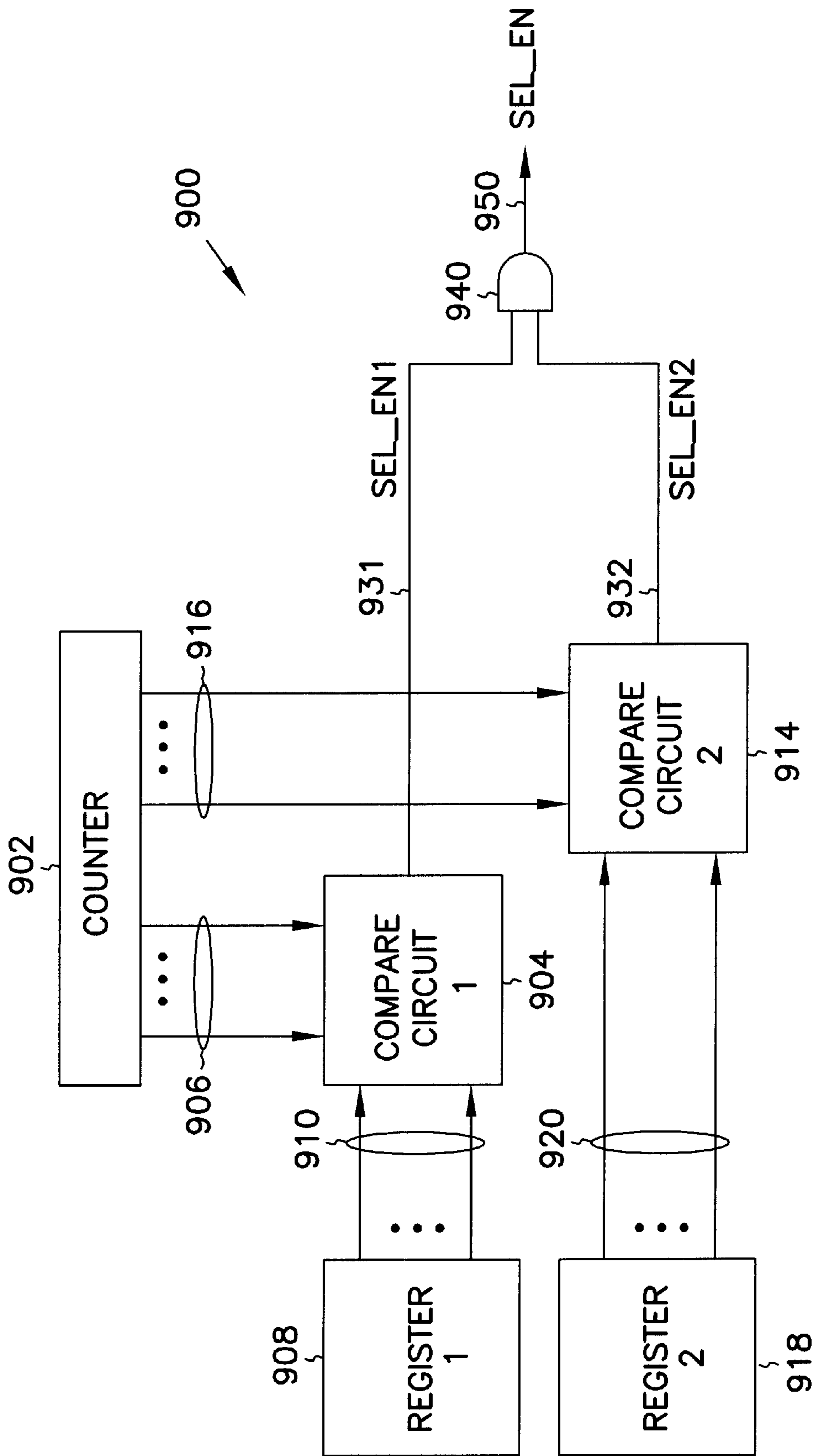


FIG. 9

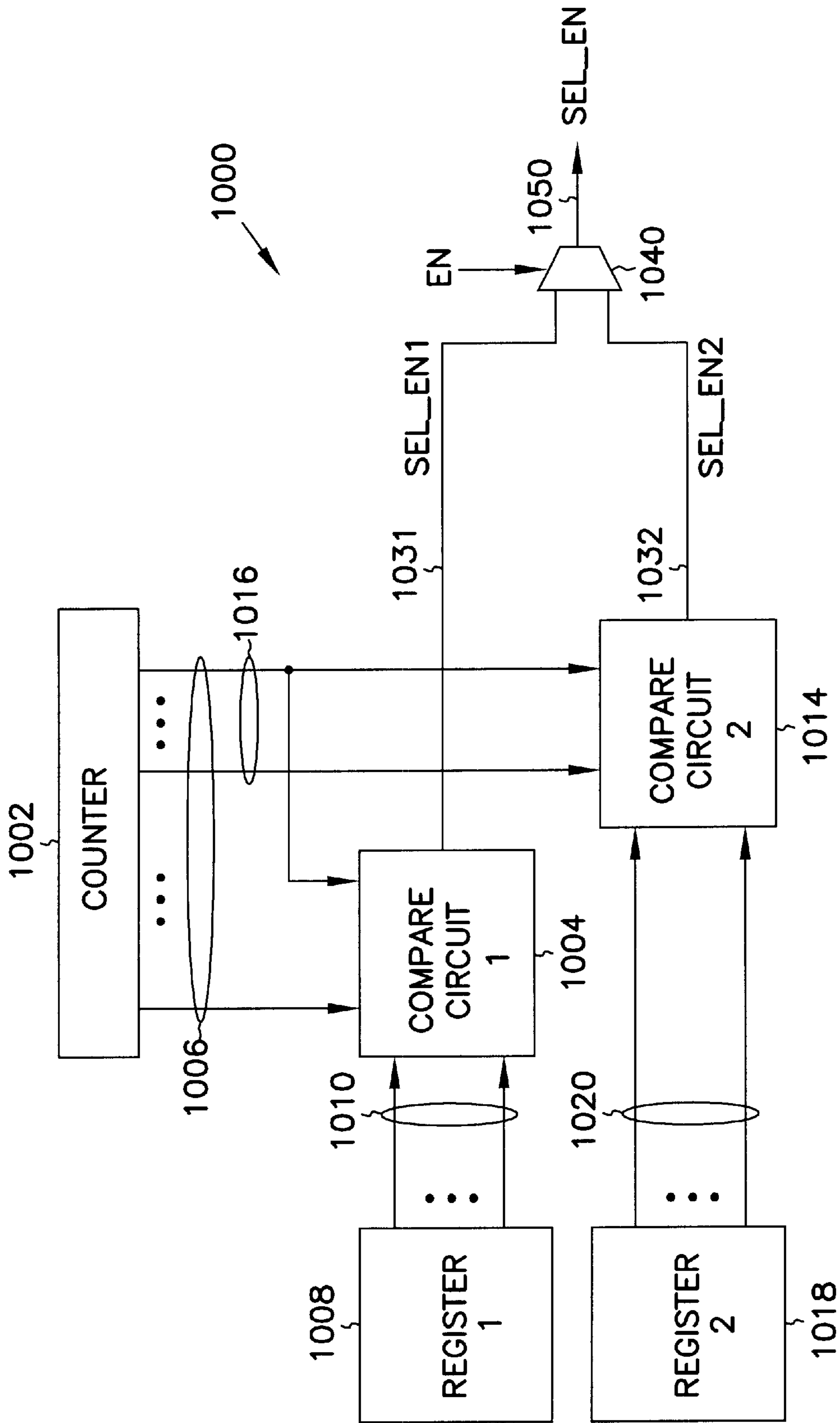


FIG. 10

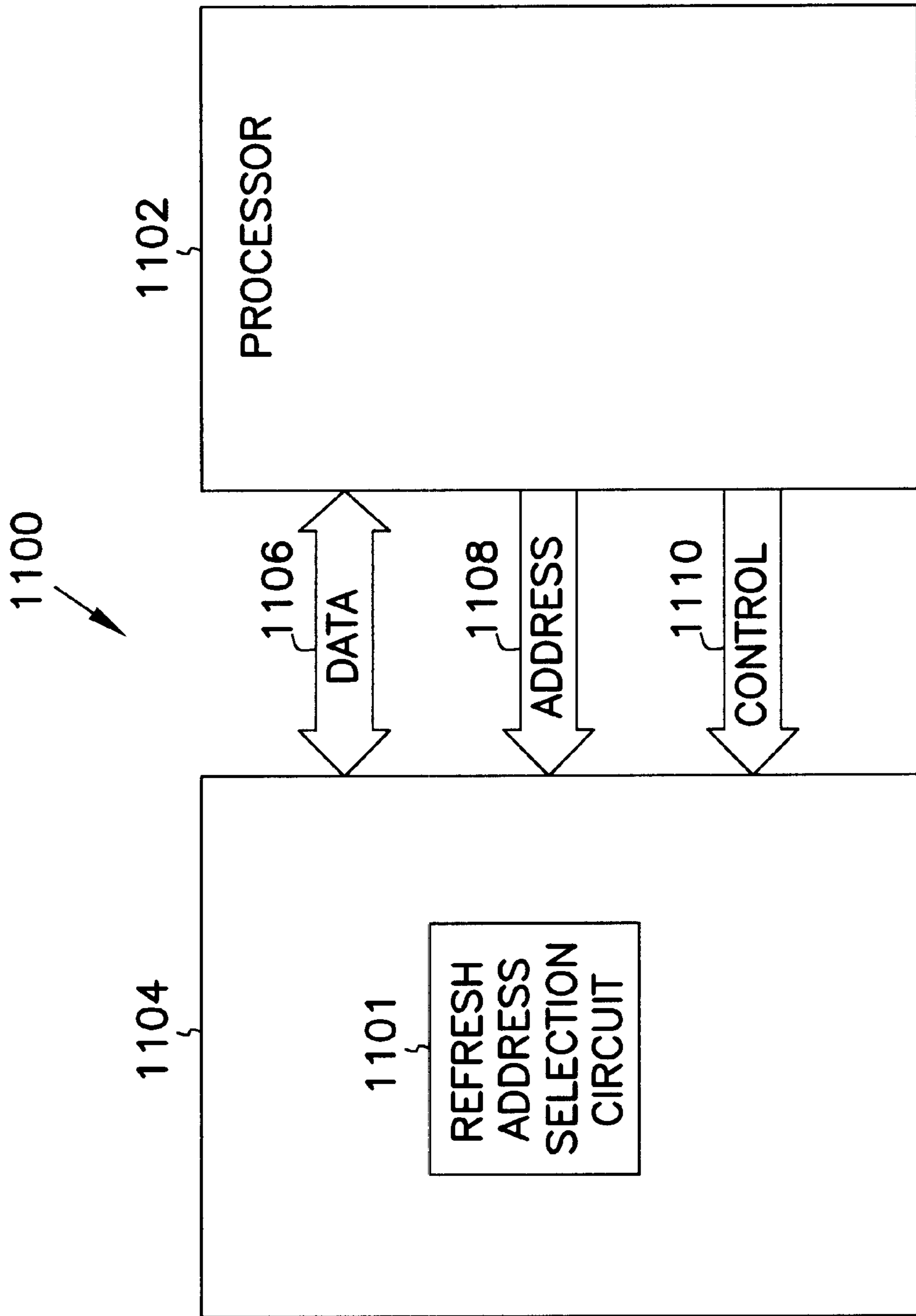


FIG. 11

## PARTIAL ARRAY SELF-REFRESH

## TECHNICAL FIELD OF THE INVENTION

The present invention relates to integrated circuits and in particular to a refresh operation in a memory device.

## BACKGROUND OF THE INVENTION

Memory devices such as dynamic random access memory (DRAM) devices are widely used to store data in computers and electronic products.

A typical DRAM device has many memory cells. Each memory cell is capable of storing a bit of data. The value of the data in each memory cell is determined by the value of a charge held by the memory cell. As a known electrical property, charge loses its value over time due to leakage and other factors, causing data to become invalid. Therefore, to retain the validity of the data, the memory cells are periodically refreshed to keep the charges at their original values.

In a typical DRAM device, the memory cells are refreshed during a refresh mode, in which all memory cells are refreshed regardless of whether all or only a portion of the memory cells contain useful data. Therefore, refreshing all memory cells during the refresh mode is not efficient.

For these and other reasons stated below, and which will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need for an efficient method to refresh memory cells in a memory device.

## SUMMARY OF THE INVENTION

The present invention includes a memory device having a refresh address selection circuit to store a number of selected rows of memory cells such that during a refresh mode only the memory cells of the selected rows are refreshed.

In one aspect, the memory device includes a counter to count addresses of rows of memory cells, a register to store selected addresses of rows of memory cells, and a compare circuit connected to the counter and the register to compare an address counted by the counter with the selected address such that a row of memory cells located at the address counted by the counter is refreshed if the address counted by the counter is within the selected addresses.

In another aspect, a method of refreshing memory cells of the memory device includes generating a count that represents an address of a row of the memory cells. The address represented by the count is compared with a selected address. Memory cells located at the address represented by the count are refreshed if the address represented by the count matches the selected address.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a memory device.

FIG. 2 is a block diagram of a refresh address selection circuit of FIG. 1.

FIG. 3 is a schematic diagram of the refresh address selection of FIG. 2.

FIG. 4 is a schematic diagram of a compare unit of FIG. 3.

FIG. 5 is a schematic diagram of another refresh address selection circuit.

FIG. 6 is a schematic diagram of a compare circuit of FIG. 5.

FIG. 7 shows a number of address ranges.

FIG. 8 shows combinations of bits that represent the number of row addresses of the address ranges of FIG. 7.

FIG. 9 is a block diagram of another refresh address selection circuit.

FIG. 10 is a block diagram of another refresh address selection circuit.

FIG. 11 is a block diagram of a system.

## DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description of the embodiments, reference is made to the accompanying drawings that show, by way of illustration, specific embodiments in which the invention may be practiced. In the drawings, like numerals describe substantially similar components throughout the several views. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized and structural, logical, and electrical changes may be made without departing from the scope of the present invention. Moreover, the various embodiments of the invention, although different, are not necessarily mutually exclusive. For example, a particular feature, structure, or characteristic described in one embodiment may be included within other embodiments. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims, along with the full scope of equivalents to which such claims are entitled.

FIG. 1 is a block diagram of a memory device **100** according to one embodiment of the invention. Memory device **100** includes a main memory **102**. Main memory **102** includes a plurality of memory cells arranged in rows and columns. Row decode **104** and column decode **106** access individual memory cells in the rows and columns in response to address signals **A0-AN** (ADDRESS), provided on address bus or address lines **110**. An input circuit **111** and an output circuit **112** connect to a data bus **114** (DATA) for bi-directional data communication with main memory **102**. A control logic **116** generates a number of command signals, such as WRITE, READ, ACTIVE, REFRESH, and RESET signals in response to control signals provided on control lines **118**. The control signals include, but are not limited to, an external clock signal XCLK, a Chip Select signal CS\*, a Row Access Strobe signal RAS\*, a Column Access Strobe CAS\* signal, and a Write Enable signal WE\*.

Memory device **100** further includes a refresh address selection circuit **154**. During a refresh mode, refresh address selection circuit **154** provides refresh address select signal SEL\_EN to control logic **116**. Based on the state of the SEL\_EN signal, control logic **116** causes memory device **100** to refresh only selected rows of memory cells. The addresses of the selected rows are stored in refresh address selection circuit **154**.

Memory device **100** describes a general embodiment of a memory device and is not a complete description of all the elements and features of a DRAM. Further, the invention is equally applicable to any size and type of memory circuit and is not limited to the DRAM described above. Additionally, the DRAM could be a synchronous DRAM commonly referred to as SGRAM (Synchronous Graphics Random Access Memory), SDRAM (Synchronous Dynamic Random Access Memory), SDRAM II, DDR SDRAM (Double Data Rate SDRAM), and Synchlink or Rambus DRAMs.



The modes of operation of memory device **100** such as write, read, and active modes are similar to that of conventional DRAM devices as known to those skilled in the art. Therefore, detailed operation of these modes are not described here. In a write mode, control logic **116** initiates the WRITE signal at the start of the write mode when certain combination of the CS\*, RAS\*, CAS\*, and WE\* signals received at input **118** is decoded by control logic **116** as valid for the write mode. Data from data lines **114** is written to memory cells in the rows and columns of main memory **102**. The address of the row of memory cells being written is provided by a combination of the address signals A0–AN on lines **110**.

In a read mode, control logic **116** initiates the READ signal at the start of the read mode when a certain combination of the CS\*, RAS\*, CAS\*, and WE\* signals received at input **118** is decoded by control logic **116** as valid for the read mode. Data is read from memory cells in the rows and columns of main memory **102**. The data is subsequently output to data lines **114**. The address of the row of memory cells being written is provided by a combination of the address signals A0–AN on lines **110**.

Before the data is written into the memory cells, or before the data is read from the memory cells, an active mode is performed. Control logic **116** activates the ACTIVE signal in the active mode at the start of the active mode when a certain combination of the CS\*, RAS\*, CAS\*, and WE\* signals is decoded by control logic **116** as valid for the active mode. During the active mode, a selected row of memory cells is activated to prepare for the read or write mode. A combination of the address signals A0–AN, which represents the address of the selected row, is decoded by row decoder **104** to activate one of the rows in main memory **102**. For example, if main memory **102** has 2,048 rows and the combination of the A0–AN signals is 0000000001 (representing the address of row **1**), then row **1** is activated. If a write mode follows the active mode, the activated row is accessed and data is written into the memory cells of row **1**. If a read mode follows the active mode, the activated row is accessed and data is read from the memory cells of row **1**.

Further, the addresses of the rows that are activated and accessed during the write or read mode are stored in address selection circuit **154**. Because the rows that are accessed contain useful data, these rows are refreshed during the refresh mode to retain the validity of the data. The non-accessed rows, which do not contain useful data, are not refreshed during the refresh mode to save time and power.

In the refresh mode, control logic **116** activates the REFRESH signal based on certain valid combination of CS\*, RAS\*, CAS\*, and WE\* signals to refresh the memory cells of main memory **102**. For example, the refresh mode is performed when a combination of the CS\*, RAS\*, CAS\*, and WE\* signals is LOW, LOW, LOW, and HIGH. During the refresh mode, refresh address selection circuit **154**, in response to the REFRESH signal, activates the SEL\_EN signal. The SEL\_EN signal is provided to control logic **116**. Based on the state of the SEL\_EN signal, control logic **116** determines which of the rows in main memory **102** is refreshed during the refresh operation.

Throughout the description, a refresh mode is referred to as a self-refresh mode. However, the embodiments described in the specification can also use other types of refresh modes known to those skilled in the art, e.g., auto-refresh.

FIG. 2 is a block diagram of a refresh address selection circuit **200** according to one embodiment of the invention.

Refresh address selection circuit **200** includes an address counter **202**, a register **204**, and a compare circuit **206**. Counter **202** includes multiple counter bit lines **212** to provide counter output signals C0–CN. Each combination of the C0–CN signals represents an address of a row of memory cells. Register **204** includes multiple register bit lines **214** to provide register output signals R0–RN. In one embodiment, a combination of the R0–RN signals represents selected addresses of rows of memory cells. In other embodiments, a state of each of the R0–RN signals represents a corresponding selected range of addresses of rows of memory cells. Compare circuit **206** connects to counter **202** and register **204** via lines **212** and **214** to receive the C0–CN and R0–RN signals. Compare circuit **206** compares the C0–CN and the R0–RN signals to provide a refresh select signal SEL\_EN on line **216**. FIG. 1 also shows the SEL\_EN signal.

During a refresh mode, counter **202** counts row addresses of memory cells in a sequential order. Each of the row address counted by counter **202** is compared with the selected row addresses stored in register **204**. Based on the comparison, compare circuit **206** activates the SEL\_EN signal accordingly. The SEL\_EN signal is provided to a control logic, such as control logic **116** of FIG. 1. Based on the state of the SEL\_EN signal, control logic **116** determines whether or not to refresh the memory cells located at the counted row addresses.

For example, when a row address counted by counter **202** is within or matches the selected row addresses stored in register **204**, compare circuit **206** asserts a LOW to the SEL\_EN signal to refresh the memory cells located at the counted row address. When a row address counted by counter **202** is not within or does not match the selected row addresses stored in register **204**, compare circuit **206** asserts a HIGH to the SEL\_EN signal to prevent a refresh of the memory cells located at the counted row address.

FIG. 3 is a schematic diagram of a refresh address selection circuit **300** according to one embodiment of the invention. Circuit **300** includes an address counter **302**, a register **304**, and a compare circuit **306**. Elements **302**, **304** and **306** represent counter **202**, register **204** and compare circuit **206** of FIG. 2. In FIG. 3, counter **302** provides the output signals C0–CN on counter bit lines **312-0** to **312-N**. Each combination of the signals C0–CN represents an address of a row of memory cells. Register **304** includes a plurality of storage elements **305-0** to **305-N** connected to a plurality of register bit lines **314-0** to **314-N**. In the embodiment represented by FIG. 3, storage elements **305-0** to **305-N** are represented by JK flip flops **305-0** to **305-5**. Each of the flip-flops **305-0** to **305-N** includes a first data input indicated by J, a second data input indicated by K, a clock input indicated by CK, and an output indicated by Q. Each flip flop is capable of storing a bit of data.

In each of the flip flops **305-0** to **305-N**, the first data input J connects to one of the address lines **324-0** to **324-N** to receive one of the address signals A0–AN. The second data input K receives a reset signal RESET. The clock input CK receives a command signal ACTIVE. Each output Q provides an output signal on one of the register bit lines **314-0** to **314-N**. For example, flip flop **305-0** connects to line **324-0** to receive address signal A0, flip flop **305-1** connects to line **324-1** to receive address signal A1, and flip flop **305-N** connects to line **324-N** to receive address signal AN. Lines **305-0** to **305-N** are part of an address bus such as address bus **110** in FIG. 1. The ACTIVE signal in FIG. 3 is also shown as the ACTIVE signal generated by control logic **116** of FIG. 1.



Compare circuit **306** includes a plurality of compare units (COMP UNIT) **318-0** to **318-N**. Each includes a first input connected to one of the counter bit lines **312-0** to **312-N** to receive one of the counter output signals **C0-CN**, and a second input connected to one of the register bit lines **305-0** to **305-N** to receive one of the register output signals **R0-RN**. Each of the compare units **318-0** to **318-N** also includes an output connected to one of a plurality of compare unit output lines **320-0** to **320-N**. Output lines **320-0** to **320-N** connect to a combinatorial circuit **330**. In the embodiment represented by FIG. 3, combinatorial circuit **330** is an OR gate **330**. OR gate **330** has an output connect to line **316**, which provides a refresh select signal **SEL\_EN**. The **SEL\_EN** signal is also shown in FIG. 2.

Refresh address selection circuit **300** further includes an address override protection circuit **333**. Address override protection circuit **333** includes inputs connected to lines **335** and **337** to receive the **A0-AN** and **R0-RN** signals and outputs connected to lines **339** to provide multiple signals **AR0-ARN**.

FIG. 4 is a schematic diagram of a compare unit **318**. Compare unit **318** represents one of the compare units **318-0** to **318-N** of FIG. 3. Compare unit **318** includes a pullup **402** and a pulldown **404**. Pullup **402** includes a p-channel transistor **412**, an n-channel transistor **422** and an inverter **406**. Transistors **412** and **422** and inverter **406** connect together to operate as a pass gate to pass a signal from line **312** to line **320**. The gate of transistor **412** connects to line **314** to receive one of the register output signals **R0-RN** indicated by **RX**. The gate of transistor **422** connects to line **314** through inverter **406** to receive an inverse of one of the **RX** signal. Pulldown **404** includes an n-channel transistor **414**. Transistor **414** has a source and a drain connected between output **320** and ground, and a gate connected to line **314** to receive the **RX** signal. In the embodiment represented by FIG. 4, line **320** represents one of the lines **320-0** to **320-N** (FIG. 3), line **312** represents line **212** (FIG. 2) and one of the lines **312-0** to **312-N** (FIG. 3), and line **314** represents line **214** (FIG. 2) and one of the lines **314-0** to **314-N** (FIG. 3). Further, the **CX** signal represents one of the **C0-CN** signals, and the **RX** signal represents one of the **R0-RN** signals (FIG. 3).

Referring to FIG. 3, during a refresh operation, counter **302** sequentially counts row addresses from row zero to the last row of the memory cells in response to the **REFRESH** signal. For example, in a memory device having 2048 rows of memory cells, counter **302** sequentially counts from row zero to row **2047**. Each counted row address is represented by a unique combination of the **C0-CN** signals presented on line **312-0** to **312-N**. Thus, to cover 2048 counts, counter **302** includes eleven counter bits lines to provide eleven corresponding counter output signals, i.e., counter bit lines **312-0** to **312-10** and eleven corresponding counter output signals **C0-C10**, where **312-10** is represented by **312-N** and **C10** is represented by **CN**. In the example, count zero is represented by a combination of 00000000000 (eleven logic 0 bits), i.e., **C0=0**, **C1=0** and all other counter bits from **C2** through **CN** are all zeros. In terms of signal level, the signal level is LOW on each of the counter bit lines **312-0** to **312-N** (**N=10**). In a similar pattern, count **1** is represented by 00000000001, i.e., **C0=1** (HIGH), **C1=0** (LOW), and count **2047** is represented by 11111111111 (all **C0-CN** are HIGH). In FIG. 3, the **REFRESH** signal is provided by a control logic such as control logic **116** shown in FIG. 1.

Compare circuit **306** compares each combination of the signals on lines **312-0** to **312-N** with the combination of the signals on line **314-0** to **314-N**. If the counted row address

on lines **312-0** to **312-N** matches the selected row addresses on lines **314-0** to **314-N**, compare circuit **306** asserts a LOW on the **SEL\_EN** signal. If the counted row address does not match the selected row addresses, compare circuit **306** asserts a HIGH to the **SEL\_EN**. The **SEL\_EN** signal is provided to a control logic such as control logic **116** (FIG. 1). Based on the state of the **SEL\_EN** signal, the control logic either allows or prevents the refresh of the memory cells located at the counted row address. In the embodiment, refresh selection circuit **300** causes the control logic to refresh memory cells at a counted row address counted when the **SEL\_EN** signal is LOW. Refresh circuit **300** causes the control logic to prevent a refresh of memory cells at a counted row address counted when the **SEL\_EN** signal is HIGH. In other embodiments, other signal levels of the **SEL\_EN** signal could be used.

The selected row addresses are stored in register **304** by either an automatic address detection method or a user program method. In the automatic detection method, flip flops **305-0** to **305-N** automatically store the row addresses of the rows that are activated during the active mode. In the user program method, the user enters the selected row address into register **304** by applying appropriate programming signals to input lines of memory device **100** such as lines **110** and **118** of FIG. 1.

In the automatic address detection method, flip flops **305-0** to **305-N** are first reset by activating the **RESET** signal and applying a LOW to all **A0-AN** signals so that flip flops **305-0** to **305-N** store a logic 0 bit and that the **R0-RN** signals are LOW. After the flip flops are reset, the **RESET** signal is deactivated (LOW). After the **RESET** signal is deactivated, the signal levels of the **R0-RN** signals depend on changes on the signal levels of the **A0-AN** signals. The **A0-AN** signals change when the **ACTIVE** signal is activated and a combination of the **A0-AN** signals activates a row during the active mode. In FIG. 3, the **A0-AN** signals represent the signals on address lines such as address lines **110** of FIG. 1. Thus, whenever the **ACTIVE** signal is activated, a row address represented by the **A0-AN** signals are automatically detected and stored into flip flops **305-0** to **305-N**. By storing the address of the activated row during the active mode, the activated row can be distinguishable from a non-activated row during the refresh mode. Therefore, during the refresh mode, only memory cells of the activated row are refreshed. Memory cells of the non-activated row are omitted from refreshing.

Using the same example above with the memory device having 2048 rows of memory cells, to store up to 2048 combinations of the **A0-AN** signals, there are eleven address lines to provide eleven corresponding address signals to eleven corresponding storage elements (flip flops). Thus, in FIG. 3, **N** is 10. In the example, row address zero is represented by a combination of 00000000000 (eleven logic 0 bits), i.e., **A0=0**, **A1=0** and all other address bits from **A2** through **A10** are all zeros. In terms of signal level, the signal level is LOW on each of the address lines **324-0** to **324-N** (**N=10**). In a similar pattern, row address **1** is represented by 00000000001, i.e., **A0=1**, **A1=0**, and row address **2047** is represented by 11111111111.

As an example, if row **0** through row **511** are accessed during the active mode, the memory cells located from row **0** to row **511** are selected as the only memory cells that are refreshed during the refresh mode. When row **511** is accessed, combination of the **A0-AN** (**N=10**) signals representing row **511** is 00111111111, where **A9** and **A10** are zeros. In FIG. 3, the 00111111111 combination is stored in flip flop **305-0** to **305-N**, in which flip flops **305** (**N-1**) and



flip flop **305-N** contain the zeros. Accordingly, except outputs Q of flip flops **305 (N-1)** and **305-N**, the signals on all outputs Q, are all HIGH.

To ensure that a lower row address does not replace the higher row address stored in the flip flops during an active mode, address override protection circuit **333** compares the **A0-AN** and the **R0-RN** signals. The **A0-AN** signals represent the address of the row being activated. The **R0-RN** signals represent the row address stored in the flip flops. The result of the comparison is provided to the flip flops in form of the **AR0-ARN** signals. If the address of the row being activated is less than the stored address, the stored address remains in the flip flops. In this case, the **AR0-ARN** signals are the same as the **R0-RN** signals are stored back to the flip flops. If the address of the row being activated is greater than the stored address, contents of the flip flops are replaced by the new address. In this case, the **AR0-ARN** signals are the same as the **A0-AN** and are stored into the flip flops as the new address.

For example, if a combination of the stored address is **0011111111** and the address of the row being activated is **001XXXXXX0**, where X can be either a logic 0 or a logic 1 bit, the address of the row being activated is less than the stored address. In this case, the stored address, i.e., **0011111111** remains in the flip flops. As another example, if the stored address is **0011111111** and the address of the row being activated is **01XXXXXXXXXX**, the address of the row being activated is greater than the stored address. In this case, the stored address is replaced by the new address, i.e., **01XXXXXXXXXX**.

To store the selected row addresses in the user programming method, the user enters the programming mode and inputs the selected row addresses. For example, the user enters the programming mode by activating a combination of signals such as the **RAS\***, **CAS\***, **WE\*** and **CS\*** signals shown in FIG. 1. Referring to FIG. 3, the flip flops are first reset by activating the **RESET** signal and forcing the **A0-AN** signals LOW so that all flip flops have logic 0 bits value and the signals **R0-RN** are all LOW. To select certain rows of memory cells for the refresh mode, the user applies an appropriate combination of signal levels to the **A0-AN** signals that represent the selected rows. For example, with a memory cells having 2048 rows, to select of row **0** to row **511** during a programming mode, **A9** and **A10** are forced LOW while **A0** to **A8** are forced HIGH. Thus, the combination of **A0-A11** is **0011111111**, where **A9** and **A10** are zeros. To enter different selected rows, for example, rows **0** to rows **32** the combination of **A0** to **A10** is **0000011111**, or to enter row **0** to row **1023**, the combination of **A0-A10** is **0111111111**. Following these patterns, other combinations can also be chosen to select row addresses.

During a refresh mode, after the flip flops **305-0** to **305-N** of register **304** contain the bits representing the selected row addresses, compare circuit **306** compares the counted row address and the selected row address to determine which memory cells are refreshed. During the refresh mode, each of the compare units **318-0** to **318-N** compares a signal on lines **312-0** to **312-N** with a corresponding signal on lines **314-0** to **314-N**. For example, in FIG. 3, compare unit **318-0** compares the signal on line **312-0** with the signal on line **314-0**, compare unit **318-1** compares the signal on line **312-1** with the signal on line **314-1**, and so on. The results from all compare units **318-0** to **318-N** are provided to OR gate **330** as the signals on lines **320-0** to **320-N**. Based on the signals on lines **320-0** to **320-N**, OR gate **330** activates the **SEL\_EN** signal accordingly. The operation of each of the compare units **318-0** to **318-N** is described in connection with the operation of FIG. 4.

Referring to FIG. 4, when the **RX** signal is HIGH, it turns on transistor **414** and turns off transistors **412** and **422**. When transistor **414** is on, it pulls the signal on line **320** to ground (LOW). When the **RX** signal is LOW, it turns off transistor **414** and turns on transistors **412** and **422**. The signal on line **320**, when the **RX** signal is LOW, depends on the signal level of the **CX** signal. Referring to FIG. 3, in the example with the memory device having **2048** rows and only the row **0** to row **511** are selected, the bits stored in the flip flops are **0011111111**. Thus, the signal levels of the **R(N-1)** and **RN** are LOW (both are zeros) while the other signal levels of the **R0-R(N-2)** are HIGH.

In FIG. 3, when the **R0-R(N-2)** signals are HIGH, the signals on lines **320-0** to **320(N-2)** are always pulled to ground (LOW). When counter **302** counts from zero up to **511**, the **R(N-1)** and **RN** signals are always LOW and the **C(N-1)** and **CN** signals are always LOW. As a result, the LOW **R(N-1)** and **RN** signals cause pullup **402** to pull the signals on lines **320(N-1)** and **320-N** to the signal level of the **C(N-1)** and **CN**, which are LOW. In this case, the signals on other lines **320-0** to **320(N-2)** are also LOW. Thus, when counter **302** counts from row zero to row **511**, all signals on lines **320-0** to **320-N** are LOW causing the **SEL\_EN** signal LOW at the output of OR gate **330**. The LOW **SEL\_EN** signals causes a control logic such as control logic **116** (FIG. 1) to allow a refresh of the memory cells located at row **0** to row **511**.

In the above example, when counter **302** counts past **511**, i.e., **512** and up, either the **C(N-1)** or **CN** signal is HIGH. For example, at count **512**, the combination of the **C0-CN** signals is represented by **01000000000**, i.e., **C(N-1)** is 1 (HIGH). At count **1023** the combination is **10000000000**, i.e., **CN** is 1 (HIGH). Therefore, when counter **302** counts passed **511**, the signal on either line **312(N-1)** or **312-N** is HIGH. Since the **R(N-1)** and **RN** signals are always LOW, they pull either the signal on line **320(N-1)** or **320-N** HIGH (the signal levels of lines **312(N-1)** or **312-N**). When any of lines **320-0** to **320-N** is HIGH (from count **512** and up), the **SEL\_EN** signal at the output of OR gate **330** is HIGH causing the control logic to prevent a refresh of the memory cells located at row **512** and up.

In summary of the above example, register **304** stores row address zero to row address **511**. During a refresh mode, when counter **302** counts from row address **0** to row address **511**, compare circuit **306** makes the **SEL\_EN** signal LOW to refresh all memory cells of row **0** to row **511** because the counted row address is within the selected row addresses. When counter **302** counts from row address **512** and up, compare circuits **306** makes the **SEL\_EN** signal HIGH to prevent a refresh of memory of row **512** and up because the counted row address is not within the stored row addresses.

FIG. 5 is a schematic diagram of the refresh address selection circuit **500** according to another embodiment of the invention. Circuit **500** includes an address counter **502**, a register **504**, and a compare circuit **506**. Elements **502**, **504** and **506** are represented in FIG. 2 as counter **202**, register **204** and compare circuit **206**. In FIG. 5, counter **502** receives a refresh signal **REFRESH** and provides the output signals **C0-CN** on counter bit lines **512-0** to **512-N** during a refresh mode. The **REFRESH** signal is similar to the **REFRESH** signal shown in FIG. 1 and FIG. 3. Each combination of the signals **C0-CN** represents an address of a row of memory cells. Register **504** includes a plurality of storage elements **505-0** to **505-3** connected to a plurality of register bit lines **514-0** to **514-3**.

Similarly to the storage elements of FIG. 3, storage elements **505-0** to **505-3** are represented by JK flip flops



**505-0** to **505-3**. Each of the flip-flops **505-0** to **505-3** includes a first data input indicated by J, a second data input indicated by K, a clock input indicated by CK and an output indicated by Q\*. In each of the flip-flops **505-0** to **505-3**, output Q\* is a complement of output Q. Each flip flop is capable of storing a bit of data.

Register **504** further includes a logic circuit **550**. Logic circuit **550** includes a plurality of AND gates **551** and inverters **552**. Logic circuit **500** further includes inputs connected to lines **554** and **556** and output connected to lines **558-0** to **558-3**. Inputs at lines **554** and **556** receive address signals A(N-1) and AN. The A(N-1) and AN signals represent the most significant bits (highest order bits) of an address which is represented by a combination of the address signals such as the A0-AN signals on line **118** of FIG. 1. Logic circuit **550** operates to decode each combination of the A(N-1) and AN signals to provide a corresponding combination of logic output signals at outputs at lines **558-0** to **558-3**.

In each of the flip flops **505-0** to **505-3**, the first data input J connects to one of the outputs of logic circuit **550** at lines **558-0** to **558-3** to receive one of the logic output signals. The second data input K of each flip flop receives a reset signal RESET. Clock input CK of each flip flop receives a command signal ACTIVE. Output Q of each flip flop provides an output signal. For example, input J of flip flop **505-0** connects to line **558-0**; input J of flip flop **505-1** connects to line **558-1**. The ACTIVE signal in FIG. 5 is also shown as the ACTIVE signal generated by control logic **116** of FIG. 1.

Compare circuit **506** includes a plurality of compare units (COMP UNIT) **518-0** to **518-3**. The number of compare units is the same as the number of storage elements. Thus, in the embodiment represented by FIG. 5, the number of compare units is four. However, in other embodiments, the number of compare units can be different than four. Each of the compare units includes first and second inputs A and B connected to two counter bit lines, a third input C connected to output Q\* of one of the flip flops, and an output connected to one of the lines **520-0** to **520-3**. The outputs of all compare units **518-0** to **518-3** connect to inputs of a combinatorial circuit **530**. In the embodiment represented by FIG. 5, combinatorial circuit **530** is represented by an OR gate **530**, which has an output connects to line **516** to provide a refresh select signal SEL\_EN. In the embodiment represented by FIG. 5, the first and second inputs A and B of each of the compare units **518-0** to **518-3** connect to counter bit lines **512(N-1)** and **512-N** in which the combination of lines **512(N-1)** and **512-N** is a subset of lines **512-0** to **512-N**. The signals provided by counter bit lines **512(N-1)** and **512-N** represent the most significant bits or the highest order bits of an address of a row of memory cells. In the embodiment represented by FIG. 5, counter bit lines CO-C(N-2) are not connected to compare circuit **506**.

FIG. 6 is a schematic diagram of compare circuit **506** of FIG. 5. In the embodiment represented by FIG. 6, each of the compare units **518-0** to **518-3** includes a plurality of logic gates and inverters indicated by AND gates **651** and **652** and inverters **653**. AND gates **651** and inverters **653** connect to inputs A and B to operate as a decoder to decode different combination of the signals provided on lines **512(N-1)** and **512-N**, which are associated with the C(N-1) and the CN signals. The result decoded from inputs A and B is provided as a combination of signals on output lines **660-0** to **660-3**. The signal on each of the lines **660-0** to **660-3** is combined with the signal on one of the R0-R3 signals on input C of a corresponding AND gate **652** to provide an output signal

on one of the lines **520-0** to **520-3**. The signals on lines **520-0** to **520-3** are provided to OR gate **530**.

In FIG. 5, flip flops **505-0** to **505-3** store a number of ranges of row addresses. For example, using the memory device with 2048 rows, the 2048 rows can be divided into, for example, four ranges. FIG. 7 shows the four ranges, 0 to 3, and their associated row addresses. As shown in FIG. 7, a first range includes row **0** to row **511**; a second range includes row **512** to row **1023**; a third range includes row **1024** to row **1535**; and the fourth range includes row **1536** to row **2047**.

Each of the four ranges is assigned to one of four flip flops **505-0** to **505-3** of FIG. 5. For example, flip flop **505-0** is assigned to the first range, flip flop **505-1** is assigned to the second range, flip flop **505-2** is assigned to the third range, and flip flop **505-3** is assigned to the fourth range. In each flip flop, the state of one of the R0-R3 signals at output Q\* indicates whether or not to refresh the rows located within the range assigned to that flip flop during the refresh mode. For example, the state of the R0 signal at flip flop **505-0** can be set such that when the R0 signal is LOW, memory cells of row **0** to row **511** are refreshed during the refresh mode, and that when the R0 signal is HIGH memory cells of row **0** to row **511** are not refreshed during the refresh mode.

The states of the R0-R3 signals depend on the values of the bits stored flip flops **505-0** to **505-3**. The values of the bits stored in the flip flops are selected by either an automatic address detection method or a user program method. In the automatic address detection method, the value of the bits stored in flip flops **505-0** to **505-3** are reset such that the R0-R3 signals are all HIGH at all outputs Q\* to indicate that none of the rows in the four ranges are refreshed during the refresh mode. After the reset, the value of the bit in a particular flip flop changes if a row within the range assigned to that particular flip flop is activated during the active mode. In the same example as shown in FIG. 7, if any one of row **0** to row **511** is activated during the active mode, the value the bit stored in flip flop **505-0** changes, i.e., from logic 0 bit to logic 1 bit, accordingly, the state of the R0 signal also changes, i.e., from HIGH to LOW. When the R0 signal is LOW, it indicates that row **0** to row **511** are refreshed during the refresh mode.

FIG. 8 shows combinations of bits that represent the row addresses from row **0** to row **2047** in the example shown in FIG. 7. As shown in FIG. 8, bits A0-A8 are represented by X's to indicate that the values of these bits can be either a logic 0 or a logic 1 depending on the address of a particular row. The difference between the ranges is based on the logic value of bits A10 and A9. For example, in range **0** (row **0** to row **511**), both A10 and A9 are zeros; in range **1**, A10 is zero and A9 is one; in range **3**, A10 is 1 and A9 is zero; and in range **3**, both A10 and A9 are zeros. In short, A10 and A9 are 00, 01, 10, and 11 in range **0**, **1**, **2**, and **3** respectively. Therefore, in the active mode, the combination of bits A10 and A9, determines which range is activated.

In FIG. 5, logic circuit **500** decodes the combination of the A10 and A9 signals on lines **554** and **556** and outputs a result as a combination of signals on lines **558-0** to **558-3** such that the value of the bits stored in flip flop are changed according to the address of a row that is activated during the active mode. Using the example shown in FIG. 7, logic circuit **550** is connected as shown so that for each combination of the A10 and A9 signals, one of the values of the flip flop **505-0** to **505-3** changes. When the A10 and A9 signals are LOW (00) the signal on line **558-0** is HIGH causing the content of flip flop **550-0** to switch from LOW to HIGH. This causes



the R0 signal to switch from HIGH to LOW ( $Q^*=LOW$ ). In a similar fashion, other combinations of the A10 and A9 signals, i.e., 01, 10, 11, also cause flip flops 550-1 to 550-3 to switch from HIGH to LOW. In summary, when the value of the bit in a particular flip flop changes, the corresponding signal level in one of the R0-R3 signals also changes to indicate that the rows of the range assigned to that particular flip flop are selected for a refresh mode.

The values of the bits in the flip flops 505-0 to 505-3 can also be selected by a user programming method. For example, the user enters the programming mode by activating a combination of signals such as the RAS\*, CAS\*, WE\* and CS\* signals shown in FIG. 1. In the programming mode, flip flops 505-0 to 505-N are first reset by activating the RESET signal and applying appropriate combinations of the A10 and A9 signals. Logic circuit 550 then causes the flip flops to reset the R0-R3 signals HIGH. To select a particular range during a refresh mode, the user applies appropriate combinations of the A10 and A9 signals so that the contents of the flip flops are changed to change the R0-R3 signals associated with the selected range from HIGH to LOW.

During a refresh operation, counter 502 sequentially counts address from row zero to the last row of the memory cells in response to the REFRESH signal. Compare circuit 506 compares a counted address represented by the C0-CN signals with the R0-R3 signals to determine whether or not to refresh the row of the counted address. Using the example shown in FIG. 7, counter 502 includes eleven counter bit lines, i.e., bits C0-C9, and C10 to represent count 0 to count 2047, where C9 and C10 are the two high order bits. Similarly to the combinations of bits that represent row 0 to row 2047 in FIG. 8, count 0 to count 2047 are represented by the same combination of bits shown in FIG. 8. Therefore the counts are divided into four ranges, in which the difference between the ranges can be identified by the two MSB, i.e., C10 and C9 ( $N=10$ ). Thus, to compare the counted address with the address of the selected range, the combination of the signals represented by the C10 and C9 signals on lines 512-N and 512(N-1) are compared with the R0-R3 signals to determine which of addresses represented by count 0 to count 2048 is in the selected range.

For example, if row 0 to row 511 (range 0 are selected, the R0 signal is LOW and the R1-R3 signals are HIGH. When counter 502 counts from zero to 511, the C10 and C9 signals are LOW (00). That means the signals on lines 512-N and 512(N-1), connected to inputs A and B, are both LOW. At compare unit 518-0 in FIG. 6, since R0 is LOW and is an input to AND gate 625 of compare unit 518-0, output 620-0 is always LOW. At other compare circuits 518-1 to 518-3, when the C10 and C9 signals are LOW, the signals on lines 660-1 to 660-3 are LOW, causing the signals on lines 520-1 to 520-3 also to go LOW. Thus, when the C10 and C9 signals are LOW (count 0 to count 511) the signals on lines 520-0 to 520-3 are LOW causing the signal SEL\_EN the output of OR gate 556 LOW. A LOW SEL\_EN signal enables the control logic to allow a refresh of row 0 to row 511.

In the above example, when counter 502 counts past 511, i.e., from count 512 to count 2047, either one or both of the C10 and C9 signals are HIGH (refer to FIG. 8). Thus, by the arrangement of compare units 518-0 to 518-3 of FIG. 6, one of the signals on lines 660-1 to 660-3 is HIGH causing one of the signals on line 520-1 to 520-3 HIGH, which makes the SEL\_EN signal HIGH. A HIGH SEL\_EN signal enables the control logic to prevent a refresh of row 512 to row 2047.

In the embodiment represented by FIG. 5, for simplicity and to concentrate in the invention, four storage elements

505-0 to 505-3 are shown to store up to four ranges of row addresses of a memory device having 2048 rows of memory cells. However, the number of storage elements can be different than four. For example, in other embodiments, the number of storage elements is eight and the 2048 rows is divided into eight different ranges with each range having fewer rows than the range when the number of storage elements is four.

In general, a relationship between the number of storage elements, compare units, and highest order counter bit lines connected to each compare unit is represented by the formula  $M=\log_2 C$ , where M is the number of storage elements, which represents the number of ranges of addresses of rows of memory cells, M is also the number of compare units. C is the number of highest order counter bit lines connected to each storage element such as lines 512 (N-1) and 512-N; C is also the number the most significant bits of an address represented by address signals, such as the A(N-1) and AN signals.

FIG. 9 is a block diagram of a refresh address selection circuit 900 according to another embodiment of the invention. Refresh address selection circuit 900 includes a combination of the refresh address selection circuits 300 (FIG. 3) and 500 (FIG. 5). In the embodiment of FIG. 9, refresh address selection circuit 900 includes a first compare circuit 904 connected to counter 902 via counter bits lines 906, and to a first register 908 via register output lines 910. A second compare circuit 914 connects to counter 902 via counter bit lines 916, and to a second register 918 via register output lines 920. Compare circuit 902 and register 908 are similar to compare circuit 302 and register 304 of FIG. 3. Compare circuit 914 and register 918 are similar to compare circuit 506 and register 504 of FIG. 5.

Refresh address selection circuit 900 further includes a combinatorial circuit 940. Combinatorial circuit is represented by an AND gate 940. The inputs of AND gate 940 connect to the outputs of compare circuits 904 and 914 via lines 931 and 932 to receive first and second select signals SEL\_EN1 and SEL\_EN2. AND gate 940 has an output at line 950 to provide a refresh select signal SEL\_EN.

First compare circuit 904 and first register 908 are constructed and operate in a similar fashion as compare circuit 306 and register 304 of FIG. 3. Second compare circuit 914 and second register 918 are constructed and operate in a similar fashion as compare circuit 506 and register 504 of FIG. 5. In FIG. 9, however, the row addresses are divided into a first and a second group of addresses. First register 908 stores a first number of selected row addresses within the first group of addresses. Second register 918 stores a second number of selected row address within the second group of addresses. For example, with the memory having 2048 rows, the first group of addresses could include addresses of row 0 to row 1023, and second group of addresses could include addresses of row 1024 to 2047. Similarly to the embodiment represented by FIG. 5, the rows in the second group of addresses are divided into ranges and register 918 includes storage elements assigned to the number of ranges of the second address group.

In the embodiment represented by FIG. 9, lines 906 are lower order counter bit lines. The signals on line 906 represent row addresses of the first group of addresses. Lines 916 are high order counter bit lines. The signals on line 916 represent row addresses of the second group of addresses.

During a refresh mode, if an address counted by counter 902 is within the first selected row address, the SEL\_EN1 signal is asserted LOW. The operation in this refresh mode



operation is similar to the operation of refresh select circuit **300** described in connection with FIG. **3**. If an address counted by counter **902** is within the second selected row address, the SEL\_EN2 signal is asserted LOW. This is similar to the operation of refresh select circuit **500** described in FIG. **5**. The SEL\_EN1 and SEL\_EN2 signals are HIGH if the counted address is not in neither the first nor the second selected row addresses.

When either the SEL\_EN1 or SEL\_EN2 signal is LOW, the SEL\_EN signal is forced LOW. At AND gate **940**, When both of the SEL\_EN1 and SEL\_EN2 signals are HIGH, the SEL\_EN signal is forced HIGH. The SEL\_EN signal is provided to a control logic such as control logic **116** (FIG. **1**). Based on the state of the SEL\_EN signal, the control logic either allows or prevents a refresh of the row at the address counted by counter **902** during the refresh mode. For example, the row is refreshed when the SEL\_EN signal is LOW and is not refreshed when the SEL\_EN signal is HIGH.

FIG. **10** is a block diagram of a refresh address selection circuit **1000** according to another embodiment of the invention. Refresh address selection circuit **1000** includes a combination of the refresh address selection circuits **300** (FIG. **3**) and **500** (FIG. **5**). A first compare circuit **1004** connects to counter **1002** via counter bits lines **1006** and to a first register **1008** via register output lines **1010**. A second compare circuit **1014** connects to counter **1002** via counter bits lines **1016** and to a second register **1018** via register output lines **1020**.

Refresh address selection circuit **1000** further includes a selector or multiplexer (MUX) **1040**. The inputs of MUX **1040** connect to the outputs of compare circuits **1004** and **1014** via lines **1031** and **1032** to receive first and second select signals SEL\_EN1 and SEL\_EN2. MUX **1040** receives a control signal EN to pass either the SEL\_EN1 or SEL\_EN2 signal to an output at line **1050** as a refresh select signal SEL\_EN. The EN signal is generated by control logic **116**.

First compare circuit **1004** and first register **1008** are similar to compare circuit **306** and register **304** of FIG. **3**. Second compare circuit **1014** and second register **1018** are similar to compare circuit **506** and register **504** of FIG. **5**. For example, in FIG. **10**, lines **1006**, like lines **312-0** to **312-N** of FIG. **3**, are the counter bit lines. Lines **1016** are subset of lines **1006** and are similar to line **512(N-1)** and **512-N**, which are subset of lines **512-0** to **512-N** of FIG. **5**.

Control signal EN at MUX **1040** is provided by a control logic such as control logic **116** shown in FIG. **1**. When the EN signal at one signal level, e.g., LOW, MUX **1040** selects the SEL\_EN1 signal to become the SEL\_EN signal; the EN signal is also set by such that when it is at another signal level, e.g., HIGH, MUX **1040** selects the SEL\_EN2 signal to become the SEL\_EN signal.

During a refresh mode, refresh address selection circuit **1000** operates like refresh address selection circuit **300** of FIG. **3** or like refresh address selection circuit **500** of FIG. **5**. For example, refresh address selection circuit **1000** operates in a fashion such as the operation of refresh address selection circuit **300** of FIG. **3** when the EN signal is set LOW. Refresh address selection circuit **1000** operates in a fashion such as the operation of refresh address selection circuit **500** of FIG. **5** when the EN signal is set HIGH. In either set up of the EN signal (LOW or HIGH), the SEL\_EN signal serves the same purpose as the SEL\_EN signal of FIG. **3** or FIG. **5**. The SEL\_EN signal is provided to a control logic such as control logic **116** (FIG. **1**). Based on the

state of the SEL-EN signal, the control logic either allow or prevent a refresh of the row at the address counted by counter **1002** during the refresh mode. For example, the row is refreshed when the SEL\_EN signal is LOW and is not refreshed when the SEL\_EN signal is HIGH.

FIG. **11** shows a system **1100** according to one embodiment of the invention. System **1100** includes a processor **1102** and a memory device **1104**. Memory device **1104** represents memory device **100** shown in FIG. **1**. Processor **1102** can be a microprocessor, digital signal processor, embedded processor, microcontroller, or the like. Processor **1102** and memory device **1104** communicate using address signals on lines **1108**, control signals on lines **1110**, and data signals on lines **1106**.

Memory device **1104** includes a refresh address selection circuit **1101**. Refresh address selection circuit **1101** is similar to refresh address selection circuit **300**, **500**, **900** or **1000**. In the embodiment represented by FIG. **11**, processor provides control to memory **1104** via control signals on lines **1110**. The control signals on lines **1110** similar to the control signals represented in FIG. **1** as the XCLK, CS\*, RAS\*, CAS\*, and WE\* signals. Based on the control signals, operating modes such as active mode and refresh mode of memory device **1104** are determined. According to the invention, during a refresh mode, refresh address selection circuit **1101** enables memory device **1104** to selectively refresh rows of memory cells that are selected by refresh address selection circuit **1101**.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement which is calculated to achieve the same purpose may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present invention. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. A memory device comprising:

a counter to count addresses of rows of memory cells;  
a register including a plurality of register cells for storing selected addresses of rows of memory cells; and  
a compare circuit including a plurality of compare units connected to the counter and the register to compare an address counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed if the address counted by the counter is within the selected addresses.

2. A memory device comprising:

a counter to count addresses of rows of memory cells;  
a register to store selected addresses of rows of memory cells; and  
a compare circuit connected to the counter and the register to compare an address counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed if the address counted by the counter is within the selected addresses, wherein the memory device further comprises: a number of counter bit lines connected to the counter; a number of register bit lines connected to the register; and a number of compare units, wherein each of the compare units connects to one counter bit line and one register bit line.

3. The memory device of claim 2, wherein the number of counter bit lines equals the number of register bit lines.



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4. A memory device comprising:  
 a counter to count addresses of rows of memory cells;  
 a register to store selected addresses of rows of memory cells; and  
 a compare circuit connected to the counter and the register to compare an address counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed if the address counted by the counter is within the selected addresses, wherein the memory device further comprises: a number of counter bit lines connected to the counter; a number of register bit lines connected to the register; and a number of compare units, and wherein each of the compare units connects one register bit line and a subset of counter bit lines.
5. A memory device comprising:  
 a counter to count addresses of rows of memory cells;  
 a register to store selected addresses of rows of memory cells; and  
 a compare circuit connected to the counter and the register to compare an address counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed if the address counted by the counter is within the selected addresses, wherein the register includes a number of storage elements to store a number of the data bits, wherein a combination of the data bits represents the selected addresses of rows of memory cells.
6. A memory device comprising:  
 a counter to count addresses of rows of memory cells;  
 a register to store selected addresses of rows of memory cells; and  
 a compare circuit connected to the counter and the register to compare an address counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed if the address counted by the counter is within the selected addresses, wherein the register includes a number of register cells to store a number of data bits, wherein one of the data bits represents the selected addresses of rows of memory cells.
7. A memory device comprising:  
 a counter including a plurality of counter bit lines to generate a plurality of count signals, each combination of the count signals representing a unique address of a row of memory cells;  
 a plurality of storage elements, configured to be programmed to form a combination of data bits that represents a plurality of rows of selected addresses of memory cells; and  
 a plurality of compare units, each of the compare units being connected to one counter bit line and to one of the storage elements for comparing an address generated by the counter with the selected addresses such that a row of memory cells located at the address generated by the counter is refreshed when the address generated by the counter is within the selected addresses.
8. The memory device of claim 7, wherein each of the storage elements includes:  
 a first data input to set the storage element to a first state in response to a reset signal;  
 a clock input to receive an active signal;  
 a second data input connected to an address line to set the storage element to a second state in response to the active signal; and

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- an output to provide an output signal identifying the state of the storage element.
9. The memory device of claim 7, wherein each of the compare units includes:  
 a pullup circuit connected to one of the storage elements and one of the counter bit lines;  
 a pull down circuit connected to the pullup circuit and ground; and  
 an output connected between the pullup and pulldown circuits to provide an output signal based on a state of the storage element.
10. The memory device of claim 9, wherein the memory device further comprises a combinatorial circuit connected to the output of each of the compare units to provide a refresh address select signal.
11. A memory device comprising:  
 a counter including a plurality of counter bit lines to generate a plurality of count signals, each combination of the count signals representing an address of a row of memory cells;  
 a plurality of storage elements to represent a plurality of ranges of addresses, each of the storage elements being configured to be programmed to represent a selected range of addresses; and  
 a plurality of compare units, each of the compare units being connected to a subset of the counter bit lines and one of the storage elements to compare an address generated by the counter with the range of addresses such that a row of memory cells located at the address generated by the counter is refreshed when the address generated by the counter is within the selected range of addresses.
12. The memory device of claim 11, wherein the memory device further comprises a logic circuit including a plurality of logic outputs to provide a plurality of logic output signals based on a combination of a plurality of address signals.
13. The memory device of claim 12, wherein each of the storage elements includes:  
 a first data input to set the storage element to a first state in response to a reset signal;  
 a clock input for receiving an active signal;  
 a second data input connected to one of the logic outputs for setting the storage element to a second state in response to a combination of the logic output signals; and  
 an output to provide an output signal identifying the state of the storage element.
14. The memory device of claim 13, wherein the memory device further comprises a combinatorial circuit connected to the output of each of the compare units to provide a refresh address select signal based on signal on the output of each of the compare units.
15. A memory device comprising:  
 a counter including a first and a second group of counter bit lines to generate a plurality of count signals, each combination of the count signals representing an address of a row of memory cells;  
 a first register to store selected addresses represented by the first group of counter bit lines;  
 a first compare circuit connected to the first register and the first group of the counter bit lines to compare an address counted by the counter with the selected addresses stored in the first register;  
 a second register to store selected addresses represented by the second group of counter bit lines;



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a second compare circuit connected to the second register and the second group of the counter bit lines to compare the address counted by the counter with the selected addresses stored in the second register; and

a combinatorial circuit connected to the first and second compare circuits to provide a refresh address select signal to refresh memory cells located at the address counted by the counter if the address counted by the counter matches the selected address stored in the first or the second register.

**16.** The memory device of claim **15**, wherein the memory device further comprises:

a number of register bit lines connected to the first register; and

a number of compare units, wherein each of the compare units connects to one register bit line and one counter bit line of the first group of the counter bit lines.

**17.** The memory device of claim **16**, wherein the number of counter bit lines of the first group of the counter bit lines equals the number of register bit lines.

**18.** The memory device of claim **17**, wherein the first register includes a number of storage elements to store a number of data bits, wherein a combination of the data bits represents the first selected addresses.

**19.** The memory device of claim **18**, wherein the second register includes a plurality of storage elements, each of the storage elements being assigned to a range of addresses represented by the second group of counter bit lines.

**20.** A memory device comprising:

a counter including a plurality of counter bit lines to generate a plurality of count signals, each combination of the count signals representing a unique address of a row of memory cells;

a first register to store selected addresses of a row of memory cells;

a first compare connected to the first register and the counter bit lines to compare an address counted by the counter with the selected addresses stored in the first register;

a second register to store selected addresses of a row of memory cells;

a second compare circuit connected to the second register and a subset of counter bit lines to compare the address counted by the counter with the selected addresses stored in the second register; and

a selector connected to the first and second compare circuits to provide a refresh address select signal based on a select signal to refresh memory cells located at the address counted by the counter if the address counted by the counter matches the selected address stored in the first or the second register.

**21.** The memory device of claim **20**, wherein the subset of counter bit lines includes counter bit lines that provide high order bits of the address of a row of memory cells.

**22.** The memory device of claim **21**, wherein the first register includes a number of storage elements to store a number of data bits, wherein a combination of the data bits represents the selected addresses of rows of memory cells.

**23.** The memory device of claim **20**, wherein the second register includes a number of storage elements to store a number of data bits, wherein a combination of the data bits represents the selected addresses of rows of memory cells.

**24.** A memory device comprising:

a plurality of rows of memory cells;

a plurality of input to receive a plurality of input signals;

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a control logic to generate a refresh command signal based on certain combinations of the input signals to initiate a refresh operation;

a counter to sequentially count addresses of the rows of memory cells in response to the refresh signal;

a register to store selected addresses of the rows of memory cells; and

a compare circuit connected to the counter and the register to compare an addresses counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed when the address counted by the counter is within the selected addresses.

**25.** The memory device of claim **24**, wherein the refresh operation is a self-refresh operation.

**26.** The memory device of claim **24**, wherein the refresh operation is an auto-refresh operation.

**27.** The memory device of claim **25**, wherein the memory device further comprises:

a number of counter bit lines connected to the counter;

a number of register bit lines connected to the register; and

a number of compare units, wherein each of the compare units connects to one counter bit line and one register bit line.

**28.** The memory device of claim **24**, wherein the memory device further comprises:

a number of counter bit lines connected to the counter;

a number of register bit lines connected to the register; and

a number of compare units, wherein each of the compare units connects to one register bit line and a subset of counter bit lines.

**29.** The memory device of claim **27**, wherein the number of counter bit lines equals the number of register bit lines.

**30.** The memory device of claim **24**, wherein the register includes a number of storage elements to store a number of the data bits, wherein a combination of the data bits represents the selected addresses of rows of memory cells.

**31.** The memory device of claim **24**, wherein the register includes a number of register cells to store a number of data bits, wherein one of the data bits represents selected range of addresses of the rows of memory cells.

**32.** A system comprising:

a processor; and

a memory device connected to the processor, the memory device comprising:

a counter to count addresses of rows of memory cells;

a register including a plurality of register cells for storing selected addresses of rows of memory cells; and

a compare circuit including a plurality of compare units connected to the counter and the register to compare an address counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed when the address counted by the counter is within the selected addresses.

**33.** A system comprising:

a processor and

a memory device connected to the processor, the memory device comprising:

a counter to count addresses of rows of memory cells;

a register to store selected addresses of rows of memory cells; and



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a compare circuit connected to the counter and the register to compare an address counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed when the address counted by the counter is within the selected addresses, wherein the memory device further comprises: a number of counter bit lines connected to the counter; a number of number of register bit lines connected to the register; and a number of compare units, wherein each of the compare units connects to one counter bit line and one register bit line.

34. The system of claim 33, wherein the number of counter bit lines equals the number of register bit lines.

35. A system comprising:

a processor; and

a memory device connected to the processor, the memory device comprising:

a counter to count addresses of rows of memory cells; a register to store selected addresses of rows of memory cells; and

a compare circuit connected to the counter and the register to compare an address counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed when the address counted by the counter is within the selected addresses, wherein the memory device further comprises: a number of counter bit lines connected to the counter; a number of register bit lines connected to the register; and a number of compare units, wherein each of the compare units connects one register bit line and a subset of counter bit lines.

36. A system comprising:

a processor; and

a memory device connected to the processor, the memory device comprising:

a counter including a first and a second group of counter bit lines to generate a plurality of count signals, each combination of the count signals representing an address of a row of memory cells;

a first register to store selected addresses represented by the first group of counter bit lines;

a first compare circuit connected to the first register and the first group of the counter bit lines to compare an address counted by the counter with the selected addresses stored in the first register;

a second register to store selected addresses represented by the second group of counter bit lines;

a second compare circuit connected to the second register and the second group of the counter bit lines to compare the address counted by the counter with the selected addresses stored in the second register; and

a combinatorial circuit connected to the first and second compare circuits to provide a refresh address select signal to refresh memory cells located at the address counted by the counter if the address counted by the counter matches the selected address stored in the first or the second register.

37. The system of claim 36, wherein the memory device further comprises:

a number of register bit lines connected to the first register; and

a number of compare units, wherein each of the compare units connects to one register bit line and one counter bit line of the first group of the counter bit lines.

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38. The system of claim 36, wherein the number of counter bit lines of the first group of the counter bit lines equals the number of register bit lines.

39. The system of claim 36, wherein the first register includes a number of storage elements to store a number of data bits, wherein a combination of the data bits represents the first selected addresses.

40. The system of claim 36, wherein the second register includes a plurality of storage elements, each of the storage elements being assigned to a range of addresses represented by the second group of counter bit lines.

41. A system comprising:

a processor; and

a memory device connected to the processor, the memory device comprising:

a plurality of rows of memory cells;

a plurality of input to receives a plurality of input signals;

a control logic to generate a refresh command signal based on certain combination of the input signals to initiate a refresh operation;

a counter to sequentially count addresses of the rows of memory cells in response to the refresh signal;

a register to store selected addresses of the rows of memory cells; and

a compare circuit connected to the counter and the register to compare an addresses counted by the counter with the selected addresses such that a row of memory cells located at the address counted by the counter is refreshed when the address counted by the counter is within the selected addresses.

42. The system of claim 41, wherein the memory device further comprises:

a number of counter bit lines connected to the counter;

a number of register bit lines connected to the register; and

a number of compare units, wherein each of the compare units connects to one counter bit line and one register bit line.

43. The system of claim 41, wherein the memory device further comprises:

a number of counter bit lines connected to the counter;

a number of register bit lines connected to the register; and

a number of compare units, wherein each of the compare units connects to one register bit line and a subset of counter bit lines.

44. A method of refreshing memory cells of a memory device, the method comprising:

generating a count that represents an address of a row of the memory cells;

comparing a bit of the address represented by the count with a bit of a selected address; and

refreshing memory cells of a row located at the address counted by the count when the address represented by the count matches the selected address.

45. A method of refreshing memory cells of a memory device, the method comprising:

generating a count that represents an address of a row of the memory cells;

comparing the address represented by the count with a selected address; and

refreshing memory cells of a row located at the address counted by the count when the address represented by the count matches the selected address, wherein com-

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paring includes comparing each bit of the count with a corresponding bit of a register that stores the selected address.

**46.** A method of refreshing memory cells of a memory device, the method comprising:

generating a count that represents an address of a row of the memory cells;

comparing the address represented by the count with a selected address; and

refreshing memory cells of a row located at the address counted by the count when the address represented by the count matches the selected address, wherein comparing includes comparing selected bits of the count with all bits of a register, wherein each bit of the register represents a range of addresses.

**47.** A method of refreshing memory cells of a memory device, the method comprising:

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storing a plurality of stored data bits that presents selected addresses of rows of the memory cells;

generating a plurality of counts, the counts representing addresses of a plurality of rows of memory cells;

comparing each of the counts with the stored data bits; and

refreshing memory cells of a row located at an address represented by one of the count when the address represented by one of the count matches the selected addresses.

**48.** The method of claim **47**, wherein storing is performed during a programming mode.

**49.** The method of claim **47**, wherein storing is performed during an active mode when a row of memory cells is activated.

\* \* \* \* \*



UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 6,650,587 B2  
DATED : November 18, 2003  
INVENTOR(S) : Casey R. Kurth, Scott J. Derner and Daryl L. Habersetzer

Page 1 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,

Item [74], *Attorney, Agent or Firm*, delete "Woesner" and insert -- Woessner -- therefor.

Column 1,

Line 9, delete "**KACKGROUND**" and insert -- **BACKGROUND** -- therefor.

Column 7,

Line 37, delete "bits" and insert -- bit -- therefor.

Line 45, delete "A11" and insert -- A10 -- therefor.

Column 10,

Line 38, insert -- of -- after "value".

Column 11,

Line 42, delete "0are" and insert -- 0) are -- therefor.

Column 12,

Line 17, insert -- of -- after "number".

Column 13,

Line 7, delete "not in" before "neither".

Line 7, insert -- in -- after "neither".

Line 7, insert -- in -- after "nor".

Line 10, delete "When" and insert -- when -- therefor.

Line 44, delete "**312N**" and insert -- **312-N** -- therefor.

Column 16,

Line 22, delete "represents" and insert -- represent -- therefor.

Column 18,

Line 62, insert -- ; -- after "processor".

Column 19,

Line 9, delete second instance of "number of" before "register".

UNITED STATES PATENT AND TRADEMARK OFFICE  
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PATENT NO. : 6,650,587 B2  
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Page 2 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 20,

Line 17, delete "receives" and insert -- receive --.

Line 27, delete "an" after "compare".

Signed and Sealed this

Fifteenth Day of June, 2004

A handwritten signature in black ink on a dotted background. The signature reads "Jon W. Dudas" in a cursive style.

JON W. DUDAS

*Acting Director of the United States Patent and Trademark Office*